DISPERSION OF LIGHT

We see colours all around us. The blue sky, green leaves, red roses, yellow sunflowers, colourful birds and butterflies, etc., are just some of the colours we see in nature. And then we have the colours of our clothes, pens, pencils, houses, vehicles, and so on. The colours we see depend on the colour of light entering our eyes from an object or a source of light. Different sources of light may produce lights of different colours. A sodium-vapour lamp, for example, produces a yellowish light. The flame of a gas stove emits blue light. But sunlight does not appear to have a colour. The same is true of certain types of bulbs we use at home. We call such light (i.e., those that appear colourless) white light.

Though white light does not appear coloured, it is actually a mixture of lights of different colours present in a definite proportion. Lights of different colours have different wavelengths. So, they behave differently. For example, they travel at different speeds. This makes the refractive index of a transparent material slightly different for different colours of lights. So, lights of different colours bend by different amounts on refraction. Therefore, under certain conditions, when white light gets refracted, its components bend by different amounts and separate out. You must have seen this happen when sunlight passing through a glass of water falls on the table or the floor, producing a band of colours. The phenomenon of splitting of light into its component colours due to the dependence of refractive index on wavelength is called the dispersion of light.

Prism

Quite often we use a glass prism to split white light. A glass prism is a five-sided solid with a triangular cross section. Thus, it has two parallel, triangular faces and three rectangular faces that are inclined to each other. In experiments, a prism is usually placed on one of its triangular faces such that its rectangular faces are vertical. Light falling on a rectangular face *(adfc* in Figure) enters the prism and emerges from another rectangular face *(befc)*.

Figure shows the cross section of a prism on which a ray of light *PQ* is incident. The ray *PQ* makes an angle *i*, with the normal to the surface at Q. Since the ray enters glass (optically denser medium) from air, it bends towards the normal. Hence, the ray bends towards the base *AB*. Within the prism, the ray travels along *QR*, and falls on the surface *CB* at *R*. At this surface, the ray passes from glass to air, and hence, it bends away from the normal. As a result, the ray bends further towards the base *AB*. Note that for the refraction at the second surface in a prism, it is a convention to denote the angle of incidence by r_2 and the angle of refraction by i_2.

You know that when a ray of light passes through a transparent rectangular slab with parallel faces, the emergent ray gets displaced parallel to itself. But a prism causes a net deviation (change in direction) in the path of a ray of light. In Figure 3.2, if the prism were not present, the ray of light would have travelled along a straight line, i.e., along *PT*. Because of the refractions at the two surfaces of the prism, the ray bends and travels along *RS* after emerging from the prism. The total angle through which the ray deviates is ________.This angle ______ is called a ray the angle of deviation. For a given angle of incidence i_1, the deviation _____ produced by a prism depends on the refractive index of the prism material. The higher the refractive index, the greater is the deviation.

Dispersion of Light by a Prism

As with any transparent material, lights of different colours travel at different speeds in the material of a prism. Hence, the refractive index of the material of a prism is different for different colours of light. So, when white light enters a prism, its different components (lights of different colours) bend by different amounts. This causes the components to separate out, or split. While emerging from the prism, they undergo a second refraction and bend further, increasing the separation between the colours. In this way, white light gets split into its component colours on passing through a prism.

Note that the component colours of white light bend by different amounts for all ref ractions. So, why does not light get split while passing through a rectangular slab? Light bends by equal angles but in opposite directions at the parallel faces of a rectangular slab. So, the components of light that split at the first refraction bend back and recombine to give white light after the second refraction. The band of colours obtained in this activity is continuous, with a colour changing to the next colour in a smooth, gradual way. In other words, there is no sharp boundary between one colour and the next. However, in this band of colours one can distinguish seven main, or prominent, colours. These are violet, indigo, blue, green, yellow, orange and red, in sequence. This sequence of colours can be remembered as VIBGYOR, which is formed by the first letters of the names of the colours. Whenever white light is split, its coloured components appear in this sequence. You see these colours in a rainbow too. When white light is dispersed, violet light deviates the most and red light de1riates the least. This means, the refractive index of the prism material is the largest for violet and the least for red. The band of different colours obtained when white light is split is an example of a spectrum, which can be defined as follows. The collection of coloured components produced by splitting light is called spectrum.

In the activity described above, white light is dispersed into its coloured components. We can recombine these components to produce white light. For this, take two similar prisms and keep the second one inverted with respect to the first (Figure 3.5). Let a narrow beam of white light fall on the combination of the prisms, and let the emergent light can be recombined by passing them through a fall on a wall. You will get a white patch prism, kept inverted with respect to the first on the wall.

The first prism splits white light into its coloured components. When these separated components pass through the second prism, they recombine to form white light. The second prism was kept inverted with respect to the first to recombine the components of white light.

Colour and the Wavelength of Light

The colour of light is related to its wavelength. Table 3.1 gives the relation between the **wavelength** and colour of light. In the table, the wavelengths are given in nanometres (1 nanometre = 1 mn = i0 m). Note that among visible lights, red has the longest wavelength, while violet has the shortest.

Table **3.1** Colours and wavelengths **of** lights

Colour	Wavelength in nm	Colour	Wavelength in nm
Violet	400-440	Yellow	570-590

Indigo	440-460	Orange	590-620
Blue	460-500	Red	620-700
Green	500-570		

Rainbows

A rainbow is perhaps the most beautiful optical phenomenon. It appears as a seven-coloured arc in the sky when there are raindrops in the air. It is visible when the sun is low in the sky (early mornings and late afternoons). To see the rainbow, you have to stand with the sun behind your back. From where does a rainbow get its colours? The colours come from the dispersion of white light by raindrops suspended in the air. Sunlight entering a drop gets refracted and is split into its component colours. The lights of the component colours travel through the drop and fall on its It other side. A part of these lights get reflected, and a part goes out. (This is *not* total internal reflection.) The reflected lights again fall on the surface of the drop and get refracted on the way out. The two refractions bend the lights through a large angle, keeping them separate. The lights of different colours emerging from the raindrops create a rainbow, with creates a rainbow red at the top and violet at the bottom. You can see the rainbow effect at fountains, water sprinklers, waterfalls, and so on. In all these cases, light is dispersed by the droplets of water in the spray. To see the effect, stand with the sun behind you when it is low in the sky.

SCATTERING OF LIGHT

Normally, when you switch on a torch, you do not see a beam of light travelling from the torch. Similarly, during the day you do not see the path of the sunlight as it illuminates things around you. However, you can see the path of light if there is dust, smoke or other small particles in the air. You might have seen the path of sunlight streaming into a room through a gap in the curtains. You might have also seen it coming down through gaps in trees in the early morning mist. In both cases, the path of the light is visible from different positions. You know that light travels in straight lines. So, for us to see the path of light from different positions, light must be redirected in different directions by the particles in its path. The phenomenon in which a part of the light incident on a particle is redirected in different directions is called scattering of light.

When light falls on small. particles, a part of it gets scattered in different directions. The rest of the light goes straight through. Do the following activity to see for yourself.

Place a glass of tap water in front of a paper screen or wall. Shine a laser pointer (or a small powerful torch) through the water. You will only see spots of light on the screen and on the walls of the glass

In this activity, the scattering of light by particles of milk in its path enables you to see the path of the light. You are able to see the path because light from each point on it reaches your eyes. You will notice that the path of the light is visible from different positions around the glass. This means that milk particles send a part of the light in all directions. The rest of the light keeps moving in the original direction, making the spot of light on the screen.

A suspension of small particles in a medium is called a colloid. Milk is a colloid in which small fat particles are suspended in water. Smoke is a colloid in which ash particles are suspended in air. Fog and mist are colloids in which droplets of water are suspended in air. You will be able to see the path of a strong beam of light through all of these. The scattering of light by the particles in a colloidal solution is called the Tyndall effect. The scattered light makes the path of light visible. The activity above is also an example of the Tyndall effect.

Scattering of Lights of Different Colours

The colours of light scattered by a suspended particle depends on the size of the particle. Very small particles scatter lights of shorter wavelengths better than those of longer wavelengths. From Table, it is clear that bluish lights have shorter wavelengths than reddish lights. When white light is incident on small suspended particles, more of the shorter wavelengths of light (bluish lights) get scattered. Very little of longer wavelengths of light (reddish lights) get scattered. So, the remaining light is reddish. The scattering of longer wavelengths of light increases as the size of the particles increases. Large particles scatter lights of all wavelengths equally well.

When smoke contains very fine particles of ash, the bluish lights get scattered, and the smoke looks milky blue. If the particles of ash are large, the entire light incident on it gets scattered. Then the smoke looks white. Clouds look white because of scattering by large drops of water in it.

Take water in a transparent container which is at least 18—20 cm long (or wide). Add two or three drops of milk to the water and shine a powerful torch through the water. Look from a side of the container. You will see that the colour of the milk—water mixture changes with distance from the torch. Near the torch, the colour is milky blue. And at the other end, the colour is orange or red. If you add a few more drops of milk, the colours become darker. Look at the face of the torch through the liquid. It will look reddish.

The suspended particles of milk scatter more of the bluish lights. This makes the mixture look bluish near the torch. As light travels down the container, the components of light left are mainly reddish in colour. So, the light looks orange or red. A similar thing happens in nature to make skies blue and the sun red when it rises or sets.

Colour of the sky

On a clear, sunny day, the sky looks blue. Sunlight travelling through the atmosphere is scattered by the molecules of gases in the air, water droplets, dust particles, and so on. Of these, the smaller ones (like gas molecules) scatter more of the bluish lights. When the scattered light reaches our eyes, it makes the sky look blue.

Air pollution over cities causes large particles to be present in the air above them. Compared to small particles, these particles scatter lights of other colours better. Thus, the scattered light has blue as well as some other components. So, the skies over cities look less blue than over open countryside.

In space, there are no particles. So, when astronauts look away from the sun, they only see darkness. This is because there is nothing to scatter sunlight. So, no light gets turned towards their eyes

Colours of the sun

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You must have noticed that the colour of the sun changes during the day. At noon, when the sun is directly overhead, the distance *AB* travelled by sunlight, through the atmosphere is short as compared to other times. So, sunlight comes across lesser number of particles, resulting in lesser scattering. Thus, around noon, the sun looks close to its actual colour, i.e., white.

At sunset or sunrise, sunlight has to travel a larger distance, *CB*. So, it comes across more number of particles which scatter mostly the bluish lights. Thus, the light reaching our eyes has more of the reddish lights. This makes the sun look orange or red.

POINTS TO REMEMBER

- White light is a mixture of coloured lights. The phenomenon of splitting of light into its component colours due to the dependence of refractive index on wavelength is called the *dispersion of light*.
- A prism causes light to be split into its component colours. The angle through which a ray of light turns on passing through a prism is called the *angle of deviation*.
- The collection of coloured components produced by splitting of light is called *spectrum*.
- In dispersion of white light, violet light bends the most and red light bends the least.
- The phenomenon in which a part of the light incident on a particle is redirected in different directions is called *scattering of light*.
- Very small particles scatter lights of shorter wavelengths (bluish lights) better than longer wavelengths. The scattering of longer wavelengths of light (reddish lights) increases as the size of the particles increases. Large particles scatter lights of all wavelengths equally well.

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